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The Effect of Wind on Precipitation Catch over a Small Hill

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Abstract. Studies of the effect of wind on precipitation distribution in areas of low hill relief by Geiger in Germany and Balchin and Pye in England stimulated a similar investigation in western Oregon. Precipitation gages located on the windward and leeward sides of a hill were checked weekly and compared with wind speed data from a nearby U. S. Weather Bureau station. During the 3-month study period, January through March 1962, the windward precipitation gage recorded only 92 per cent of the total of the leeward gage. The leeward gage received more precipitation than the windward gage during 9 of the 11 weeks in which precipitation occurred during the 13-week study period. It was also noted that the higher the wind velocities during precipitation the greater the catch on the leeward side of the hill except during a period of snowfall with moderate winds, when this distribution was reversed.

Introduction. Many studies have shown that precipitation varies greatly over small areas [e.g., *Balchin and Pye*, 1948; *Geiger*, 1959; *Huff and Neill*, 1957; *Linsley and Kohler*, 1951; *Stout*, 1960; *Styber*, 1961]. In 1962 a study was conducted on Gillespie Butte in western Oregon to determine the distribution of precipitation over a small hill. This study was primarily stimulated by the findings of *Geiger* [1959, p. 246] in Germany in 1926, and of *Balchin and Pye* [1948, pp. 364, 366] in England in 1944–1946.

Geiger claimed that the orographic effect does not come into play (at least in middle Europe) on a hill low enough not to be a factor in the rising, and thus in the cooling, of inflowing air. As cooling with ascent normally amounts to approximately 1° per 300 feet of vertical rise, we might suppose that a hill less than 300 feet higher than the surrounding area would be of little consequence in the determination of the distribution of local hill precipitation. Geiger concluded, however, that the distribution of precipitation as measured in gages installed in the normal manner (with the axis of the gage at a 90° angle to a horizontal plane and not oriented with the ground slope) on a hill is just the opposite of that for gages on a high mountain; the windward slope receives less precipitation because the wind blows the precipitation over the vertical rain gage, and the leeward side receives more because the gage is sheltered from the wind.

Balchin and Pye reached a somewhat different conclusion regarding the Bath area of England. Even when dealing with minor relief features, they found that gages on the windward slopes of hills generally received greater precipitation totals than the leeward sides. Moreover, they observed that with high wind velocities the maximum fall was displaced from near the crest of the windward slope to the leeward slope.

Studies in Japan [*Masatsuka*, 1960] have shown that meteorological (with normal gage installation) rainfall is about 30 per cent less than hydrologic (gage oriented with ground slope) rainfall on the windward slope and about 10 per cent more on the leeward slope—a conclusion somewhat similar to that of *Geiger* [1959].

Description of the study area. Figures 1 and 2 show the pertinent details of the surrounding terrain and the setting of the precipitation gages on Gillespie Butte. The butte is located at the upper or southern end of the Willamette River valley. The Cascade Mountains attain elevations of 10,000 feet 75 miles to the east, and the Coast Range reaches heights of 2500 feet directly to the west. The Pacific Ocean lies only 50 miles to the west.

Instrumentation and method. The precipitation gages used in this investigation were exact replicas of the forestry rain gage. (The forestry gage is an exact replica of the standard 8-inch nonrecording rain gage with the

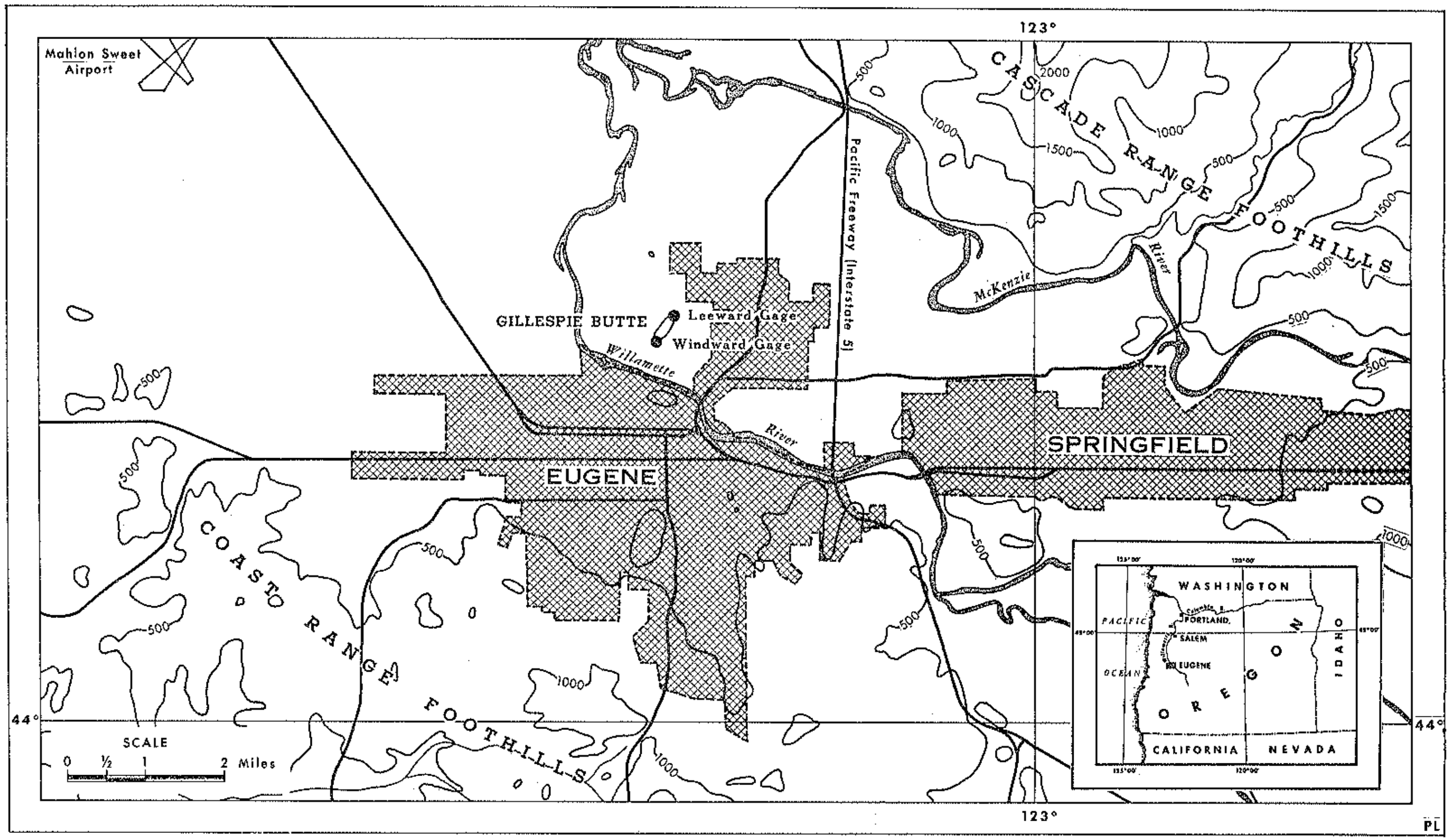

Fig. 1. Index map showing the location of the Gillespie Butte study area. (Elevations are in feet.)

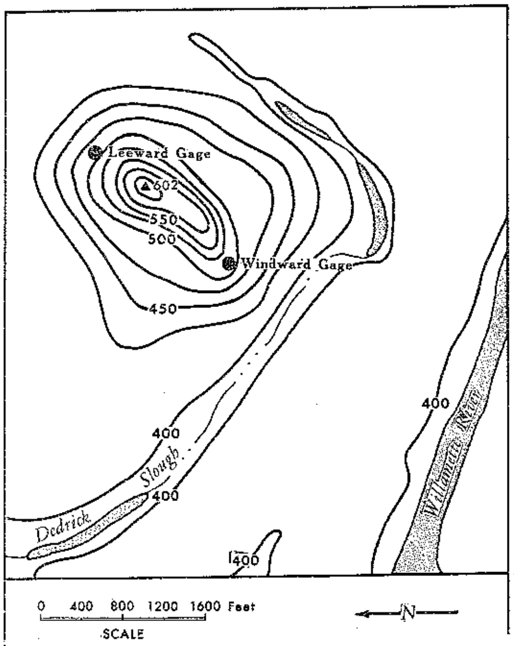

Fig. 2. Relief patterns of Gillespie Butte and gage sites.

following exceptions: (1) the inside diameter of the orifice of the receiver is 7 11/16 inches, not 8 inches, (2) the measuring tube is only 5 inches long and thus holds only 0.50 inch of liquid precipitation, not 2.00 inches like the standard rain gage, and (3) the overflow can is correspondingly shorter than that of the standard rain gage, having a capacity of only 7.50 inches, including the measuring tube.) The gages were installed on a 1-inch-thick board on the ground surface in the normal manner (with the axis of the gages at a 90° angle to a horizontal plane and not oriented with the ground slope). Frozen precipitation was melted in the field by adding a given amount of hot water to the catch and obtaining the liquid content of the solid precipitation.

From January 1, 1962, through March 31, 1962, information was recorded weekly and monthly from the two gages. The limitation on the frequency of reading was due to the amount of time required to visit the rain-gage stations. It was also thought that a 3-month period during the wet and windy season of the year in western Oregon (approximately 40 per cent of the annual precipitatoin normally falls during the January–March period) would indicate trends in precipitation distribution over Gillespie Butte.

The windward gage was completely open to the prevailing southerly winds (during frontal passages) with no natural shielding, and the leeward gage had a very good wind shield to the south in the mass of the butte itself.

Conclusion. During the 3-month study period, January through March 1962, the Gillespie Butte windward precipitation gage recorded only 92 per cent of the total leeward gage precipitation (see Table 1). The leeward gage received more precipitation than the windward gage during 9 of the 11 weeks in which precipitation occurred during the 13-week study period. The largest percentage difference was recorded during the week of January 1 to 7, when the windward gage recorded only 76 per cent of the leeward gage total for that week. In one of the two weeks (January 15–21) in which the windward gage received more precipitation than the leeward gage, wind-driven snow which blew over and past the leeward gage,

TABLE 1. Total Precipitation Measured at Gillespie Butte, January 1 to April 1, 1962

Period	Total Precipitation, Leeward Gage, in.	Total Precipitation, Windward Gage, in.
January 1–7	0.99	0.75
January 8–14	0.28	0.27
January 15–21	0.50	0.69
January 22–28	0	0
January 29–February 4	0	0
January total	1.77	1.71
February 5–11	1.51	1.39
February 12–18	1.49	1.30
February 19–25	0.32	0.26
February 26–March 4	1.52	1.28
February total*	3.65	3.26
March 5–11	0.81	0.76
March 12–18	0.08	0.06
March 19–25	2.62	2.39
March 26–April 1	1.54	1.59
March total*	6.24	5.77
January–March total	11.66	10.74

* To obtain the February and March monthly totals, the gages were checked on February 28 (the last day of February). As there was considerable precipitation during the week of February 26 to March 4, the weekly totals indicated in Table 1 do not add up to the monthly totals shown.

TABLE 2. Average and Fastest One-Minute Wind Speeds Recorded at Mahlon Sweet Airport for Selected Weeks

Week	Average Wind Speed during Precipitation, mph	Fastest Observed One-Minute Wind Speed, mph	Leeward Precipitation in Excess of Windward
January 1–7	11.8	35	0.24
February 12–18	9.6	31	0.19
February 26–March 4	11.9	29	0.24
March 19–25	13.9	29	0.23

but directly into the windward gage, was responsible for the leeward gage recording only 72 per cent of the windward total. Synoptic factors outside the study area (a slowly moving cold front) coupled with low local wind speeds caused the slightly higher total at the windward gage during the week of March 26 to April 1, 1962. It was also found that the higher the wind velocities during precipitation the greater the catch on the leeward side of the hill compared with that on the windward side (see Table 2).

In short, the assumptions made by Geiger in Germany in 1926 were found to be generally true during the 3-month investigation at Gillespie Butte.

The distribution of precipitation on the micro-scale certainly varies with terrain and climatic aspects. Possibly these variations can be areally delimited when more observations are analyzed. Further investigations of this nature in other areas will be necessary if the true trend of precipitation distribution in areas with low hilly relief is to be determined. As was noted, investigations in England in 1944–1946 [*Balchin and Pye,* 1948, pp. 364, 366], did not completely bear out Geiger's findings in Germany in 1926 or those determined at Gillespie Butte in 1962, although similarities existed at all three locations.

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